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MINERAL POLICY SECTOR
*INTERNAL REPORT*

Energy Mines and Resources Canada, Mineral Policy Sector
MRI 80/10

# THE EFFECT OF SMELTER-REFINERY LOCATION ON TRANSPORT COSTS FOR YUKON LEAD AND ZINC PRODUCTION

by D.D. Brown

# The Effect of Smelter-Refinery Location on Transport Costs for Yukon Lead and Zinc Production

**D.D. BROWN**
**Regional Planning Section**
**Resources and Development Division**

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OTTAWA

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# THE EFFECT OF SMELTER-REFINERY LOCATION ON TRANSPORT COSTS FOR YUKON LEAD AND ZINC PRODUCTION

by

D.D. Brown
Regional Planning Section
Resources and Development Division

May 1980

# PREFACE

This report is an analysis of transport costs associated with smelting Yukon lead and zinc concentrates in the Yukon and B.C. compared with smelting these concentrates in Japan. A government-industry study is currently underway to examine the economics of lead and zinc smelting and refining in British Columbia. A B.C. smelter may utilize concentrates originating partly or mainly in the Yukon. EMR supports and is participating in the B.C. study, but recognizes the aspirations of Yukon residents to realize the economic benefits of further processing in the Yukon Territory. Accordingly some analysis is required in parallel with the B.C. study to evaluate relative cost advantages and disadvantages of Yukon versus B.C. smelter sites, and other relevant considerations. This study on transport costs is intended to contribute to this need.

Robert J. Shank
Director
Resources and Development Division

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# INTRODUCTION

## Objective of Report

This report estimates order of magnitude transport costs for mine concentrate and other smelter inputs, and metal outputs, for possible combined lead-zinc smelter complexes at Prince Rupert, B.C., Whitehorse and Pelly River Terminal, Y.T. Transport costs for smelter byproduct sulphuric acid are not considered except for the cost of delivery from the Yukon to Skagway, on the assumption that acid could possibly be sold f.o.b. Pacific coast ports at a zero price. Two sets of options are presented: "A" options are based on a smelter with output of 100,000 tpa of zinc and 50,000 tpa of lead. "B" options are based on a smelter with output to 200,000 tpa of zinc and 100,000 tpa of lead. The Cyprus Anvil mine near Faro could supply the concentrate requirements for option A, but new production (e.g. from the Howard's Pass property of Placer Development Limited or other properties) would be required for option B. Table 1 summarizes the annual tonnages of smelter inputs and outputs for the two option sets.

Table 1. Annual Tonnage of Smelter Inputs and Outputs

| | | | OPTION A | OPTION B |
|---|---|---|---|---|
| | | | short tons per annum (tpa) | |
| OUTPUT CAPACITY | zinc smelter[1] | | 100,000 | 200,000 |
| | lead smelter[2] | | 50,000 | 100,000 |
| INPUTS | lead and zinc concentrate | | 307,000 | 614,000 |
| | smelter supplies[3] | | 49,100 | 98,200 |
| | | Total | 356,100 | 712,200 |
| OUTPUTS | sulphuric acid | | 229,000 | 458,000 |
| | lead and zinc metal | | 150,000 | 300,000 |
| | | Total | 339,000 | 758,000 |

Sources: Jan. H. Reimers and Associates Ltd., Feasibility Study of a Zinc-Lead Smelting Complex for Cyprus Anvil Mining Corporation, 1974; and Wright Engineers Ltd. and H.R. Halvorson Consultants Ltd., Evaluation of a Metallurgical Complex in British Columbia, 1979.

[1] A roast-leach-electrolysis smelter system with a sulphuric acid plant.

[2] An electrical furnace smelter in conjunction with the same sulphuric acid plant as under 1.

[3] Of 49,100 tons of smelter supplies under option A, 43,800 tons are accounted for by silica flux and limestone required for the lead smelter; the remainder consists of ammonia (2,600 tons), coke (2,600 tons) and supplies and spare parts (100 tons). The silica flux and limestone should be obtained within a reasonable rail or road distance, or be supplied by coastal barge to coastal smelter locations. Quantities are doubled under option B.

## Background

The Yukon is one of the world's major lead and zinc province Two mines are in production but exploration to date has identified several other deposits which have not yet been developed (Figure 1). These include the Grum, Vangorda and Swim Lake deposits near Faro, the Tom and Jason deposits in Macmillan Pass, and the Howard's Pass deposi which potentially is one of the world's largest (other deposits shown Figure 1 contain copper or tungsten).

The existing lead-zinc mines are Cyprus Anvil Mining Corporation, which produces approximately 425,000 tons[1] of lead and zinc concentrates a year, and United Keno Hill Mines Limited which is primarily a silver mine but which produces approximately 12,000 tons of lead and zinc concentrate annually. Cyprus Anvil markets its concentrate mainly in Japan, with smaller sales in Europe and elsewhere. United Keno Hill markets its silver-lead and zinc concentrates in the U.S. and Canada, respectively.

Concentrate from both mines is trucked to the White Pass and Yukon Railway (WPY) at Whitehorse and then railed to the port of Skagwa Alaska. Cyprus Anvil concentrate is then shipped from Skagway directly to overseas markets while that from United Keno Hill is shipped to Vancouver in WPY container vessels and thence to smelters by rail.

Development of additional mines in the Yukon is expected in the 1980's but is dependent on the expansion of infrastructure and services, notably transportation and electric power. A number of studi have been undertaken or are underway on transport and power options but a key problem is that governments are not prepared to commit the large sums necessary until firmer commitments are made on new mine development

On transportation, two basic options are (1) to expand and upgrade the existing highway and trucking system beyond Whitehorse, and (2) to extend the WPY Railroad northeastward towards the Faro-Ross River area where a new truck-rail terminus, at Pelly River Terminal, would be established to serve future mines in the promising Faro, Howard's Pass and MacMillan Pass areas. The rail extension option is predicated on the retention and rehabilitation of the present Skagway-Whitehorse railway, a matter which is presently uncertain due to the poor financial and physical shape of the railway. A report on a CTC inquiry into the railway was submitted in February 1980 to the Minister of Indian Affairs and Northern Development (IAND) who, at time of writing, was reviewing alternative methods of ensuring continued rail operation. While shippin alternatives exist for present rail users (e.g. trucking via the Carcross-Skagway or Haines roads) closure of the railway probably would considerably dampen prospects for new mine development in the Yukon.

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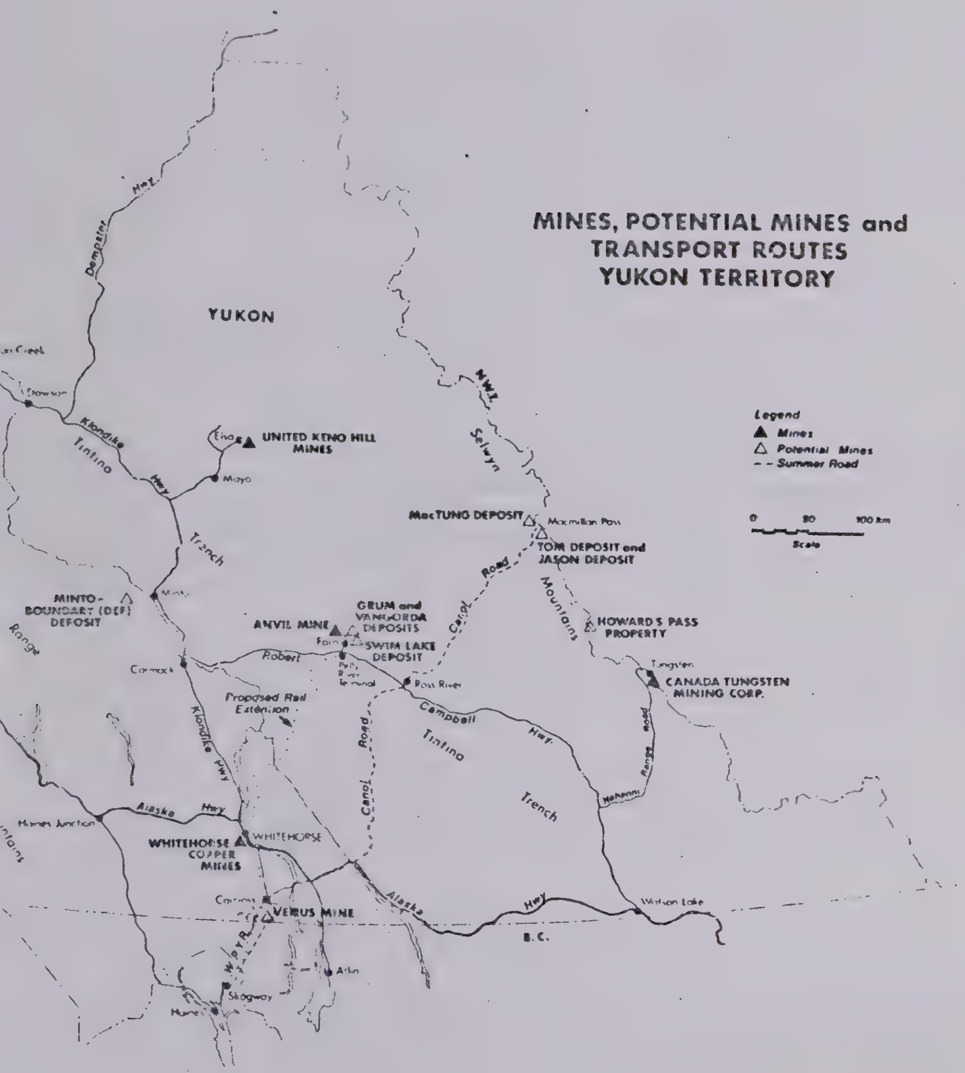
[1] Short tons of 2,000 pounds avoirdupois.


MINES, POTENTIAL MINES and TRANSPORT ROUTES YUKON TERRITORY
Legend
▲ Mines
△ Potential Mines
- - Summer Road
0 50 100 km
Scale
YUKON
N.W.T.
B.C.
Dempster Hwy
Klondike Hwy
Tintina Trench
Selwyn Mountains
Canol Road
Robert Campbell Hwy
Alaska Hwy
Nahanni Range Road
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Proposed Rail Extension
UNITED KENO HILL MINES
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TOM DEPOSIT and JASON DEPOSIT
HOWARD'S PASS PROPERTY
Tungsten
CANADA TUNGSTEN MINING CORP.
MINTO-BOUNDARY (DEF) DEPOSIT
ANVIL MINE
GRUM and VANGORDA DEPOSITS
SWIM LAKE DEPOSIT
Faro
Pelly River Terminal
Ross River
Carmacks
Haines Junction
WHITEHORSE COPPER MINES
WHITEHORSE
Carcross
VERUS MINE
Atlin
Skagway
Haines
Watson Lake

Fig. 1

## Opportunities for Further Processing

Much of the nonferrous metal concentrate now produced in western Canada is exported to smelters in Japan and elsewhere. Cyprus Anvil, as a condition of government financial assistance in support of its initial development, in 1974 studied the viability of lead and zinc smelting and refining in the Yukon but concluded that they would be uneconomic. An updating of the 1974 analysis was scheduled to be presented to IAND early in 1980 but has been delayed; it is reported to have broadened the analysis to consider sites in British Columbia as well.

Lead and zinc concentrate supply could expand significantly in the next decade from new mines in the Yukon, B.C. and N.W.T. A joint industry-government study is now investigating the feasibility of establishing zinc and lead smelters in B.C. to process some of this future output.

Previous analysis has suggested that smelting-refining economics are more favorable at a site in British Columbia, especially a coastal site, than in the Yukon, even if all the concentrate feed originates in the Yukon. Notwithstanding other cost disadvantages in the Yukon, processing requires considerable electric power and it is uncertain whether generating plants with sufficient electrical power capacity will be constructed in the Yukon for another decade.

Processing economics might be improved in the Yukon, however, through the application of new process technologies, some of which potentially can treat bulk lead-zinc concentrate. The existing Imperial Smelting process also can treat a bulk concentrate and its main energy form is coke, which may be producible from indigenous coals. Accordingly, and in the context of electric power demand and other studies, there is a need to continue analysis on the economics of processing in the Yukon. Regional Planning Section currently is reviewing implications of alternative processing technologies for lead and zinc processing economics in the Yukon.

Transport costs for concentrate versus smelter-refinery outputs also can have an important influence on the locational economics of processing. Accordingly, this paper reports on an analysis of transport cost implications of smelting Yukon lead and zinc concentrate in the Yukon compared with sites in coastal British Columbia and Japan.

## Yukon Mine Potential and Possible Yukon Rail Extension

Attention concerning future power, transportation and smelter developments in the Yukon Territory has been based almost entirely on lead and zinc production of the Cyprus Anvil mine and potential mine production from lead-zinc properties such as the Grum, Howard's Pass, Tom and Jason (Figure 1). The objective of a Yukon rail extension, from Whitehorse toward the Anvil district, would be to provide a lower cost

and more efficient transport system to haul mine concentrates from these mine properties to the port of Skagway. The objective of a Yukon lead-zinc smelter complex would be to enhance the regional economic and public benefits through further processing of mineral concentrates, and to provide an adequate return on capital while minimizing public costs related to environmental damage. Because the Yukon is remotely located for industrial development of this kind and costs are correspondingly higher than in southern, less remote regions, consideration has been given to a smelter site in the Prince Rupert/Kitimat area, on the western terminus of the Canadian National Railway's northern mainline. This area has the advantage of direct access to both ocean-shipping and the continental rail system, and of being able to serve lead-zinc processing requirements of mines in northern British Columbia, the Yukon Territory and Northwest Territories. Electric power and other infrastructure are also available now.

While transportation economics are not the only consideration in locational economics of smelting and refining, they are an important element in the evaluation process. To date, lead-zinc mines in the Canadian northwest such as the Cyprus Anvil and Pine Point mines, have had to absorb high transport charges to deliver mine concentrates to domestic and overseas markets. For the Cyprus Anvil mine, unit ton-mile rates on the 110 mile railway are about three times greater than for comparable rail shipments in other regions of Canada. Its truck movement of some 425,000 tons of concentrate over 238 miles is the largest of its kind in Canada in terms of ton-miles of lead-zinc concentrate and ton-mile rates are higher than on southern roads because of remoteness, high maintenance and rapid equipment wear associated with gravelled roads, and the low volume of backhaul traffic.

## Smelting Technology, Inputs and Outputs

Lead and zinc concentrate consist of metallic sulphide and gangue minerals. A typical concentrate contains 50 to 60 per cent metal. Small amounts of silver or other recoverable metals add little to weight of concentrate but can add much to its value. In smelting and refining, the principal and byproduct metals are recovered in relatively pure form; sulphur is fixed as sulphur dioxide ($SO_2$) gas which can be converted to sulphuric acid, or as elemental sulphur. The waste constituents are discarded in slag and residues. Because exhaustion of $SO_2$ gas to the atmosphere is no longer permitted from new smelters in Canada, the only practical option with most conventional smelting processes is to convert $SO_2$ to acid. However, some hydrometallurgical processes, such as the Cominco-Sherritt process, are capable of fixing the sulphur directly in elemental form.

In conventional smelting and refining the tonnage of smelter outputs exceed the tonnage of smelter inputs - principally concentrate (Table 1). Hence, transport tonnage is not reduced through processing. Where a smelter is favourably located with respect to phosphate fertilizer markets, outgoing shipping tonnage can be reduced somewhat by using the sulphuric acid to produce phosphoric acid or phosphate fertilizer,

but the input/output balance becomes more complicated because it involves the transport of phosphate rock to the smelter and phosphoric acid to fertilizer plants or fertilizer to markets. Thus, each smelter site has its own set of transport logistics and costs once processing technology and markets are defined. The final evaluation of a project then must rest on a thorough feasibility study based on a solid assessment of markets.

## TRANSPORT AND SMELTER OPTIONS

To illustrate the impact of transport costs on processing cations, two sets of hypothetical smelter options are presented in is report. Under the "A" series a smelter with an annual output of 0,000 tpa of zinc and 50,000 tpa of lead is considered at one of three tes - Pelly River Terminal, Y.T., Whitehorse, Y.T., or Prince Rupert, C.. Under the "B" series a smelter with annual capacity double that the "A" series (200,000 tpa of zinc and 100,000 tpa of lead) is nsidered at the same three sites.

Transport options depend on smelter location and existing and tential transport routes and multi-modal transport systems. Under the " series, all concentrate (307,000 tpa) is assumed to originate at the prus Anvil mine and other mines in the same area. Under the "B" ries, concentrate requirements (614,000 tpa) are assumed to originate the Cyprus Anvil mine and other area mines (425,000 tpa) and the ward's Pass property which is located near the Yukon-Northwest Terri- ories boundary (189,000 tpa). The assumed mineral concentrate and etal flows under options A-1 to A-5 and B-1 to B-5 are shown in Figure , which also identifies inter-modal transfer points (truck/rail and ail/ marine).

Options A-1 and B-1 assume a smelter location at Prince Rupert ith concentrates trucked to Whitehorse, railed to Skagway and barged to rince Rupert. A-2 and B-2 are the same except extension of the railway rom Whitehorse to Pelly River Terminal displaces trucking on this egment. A-3 and B-3 assume a smelter at Pelly River Terminal served by he Yukon rail extension. A-4 and B-4 assume a smelter at Whitehorse hich receives concentrate by truck and ships metal by rail to Skagway. -5 and B-5 are the same except extension of the railway to Pelly River erminal is assumed. All cases assume for simplicity that metal is hipped directly to Japan via the ports of Skagway or Prince Rupert. ore likely markets are the U.S. and perhaps other Pacific and European reas but attempts to estimate the shipping bill from a Canadian smelter o these areas would excessively complicate the analysis.

### ssumptions

The transport cost model is based on the following assumptions*:

1) all transport charges or rates are in constant 1978 dollars;

2) all new roads are constructed by the federal and/or territorial government and user fees are based on normal fuel taxes and license fees;

3) all capital charges and operating costs associated with the Yukon rail extension are recovered from user-fees. Capital expenditures are amortized or depreciated over a 24-year period at an annual compound interest rate of 10 per cent;

TRANSPORT/SMELTER OPTIONS FOR YUKON LEAD AND ZINC MINE CONCENTRATE AND SMELTER OUTPUTS

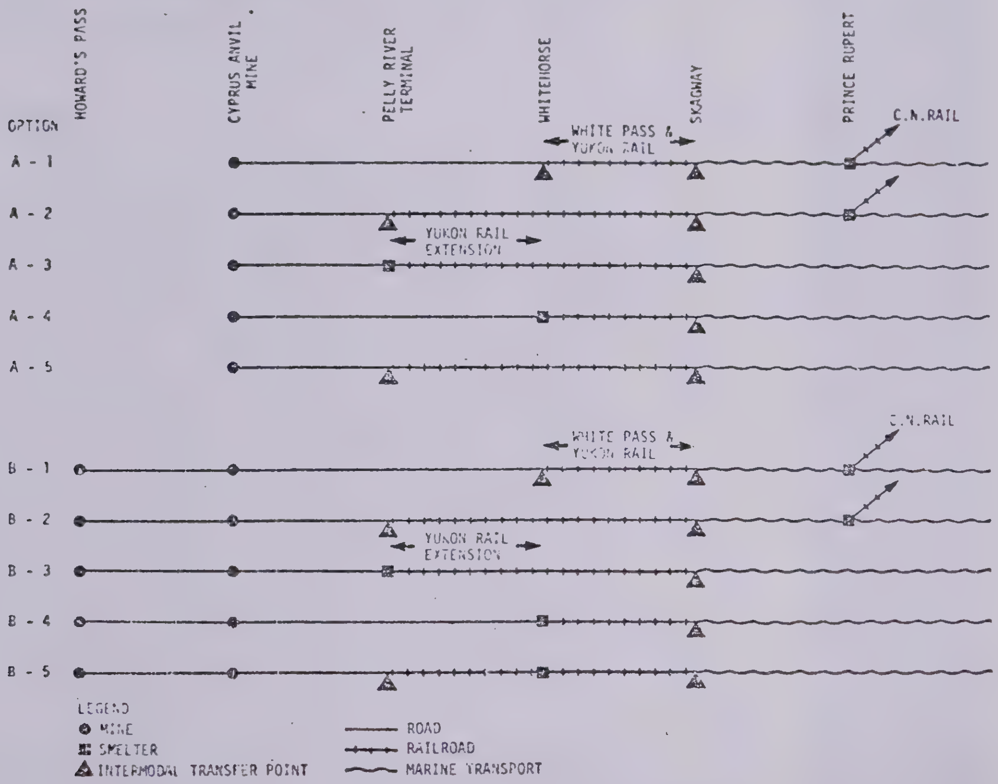

Fig. 2

) silica flux is trucked from a point 35 miles west of Carmacks to Yukon smelters; limestone is trucked from a point 20 miles east of Carmacks to Yukon smelters. The Prince Rupert smelter complex is supplied with silica flux and limestone by coastal barges.

) other supplies to mine areas, such as gasoline, diesel fuel and general supplies, will not form a significant proportion of Yukon rail extension traffic.

) transport costs for sulphuric acid beyond Skagway and Prince Rupert are not considered.

The objective of the model is to determine the least cost ansport option and smelter site option given the basic assumptions and compare total transport system costs between options. An approximate stimate of sensitivities to various market destinations can be made.

## rivation of Transport Charges

Truck and rail transport rates for concentrate used in this eport are derived from actual or typical rates applicable to mineral oncentrate movements in the Yukon Territory during 1978. Other charges, ich as truck rates from Howard's Pass to truck/rail transfer points or nelter sites in the Yukon Territory, are estimated on the basis of 1978 ates. The most tenuous rate estimates are those for rail on a potential tension of the White Pass and Yukon Railway from Whitehorse, to Pelly ver Terminal, near Faro, Y.T.; the estimates are based on data in a 978 report by Swan Wooster Engineering Co. Ltd. for IAND, entitled "The kon Transportation Study" and the assumption that transported tonnage ill bear the full capital and operating costs. Marine freight rates e based on a range of actual ocean rates and on estimated rates for arging between Skagway and Prince Rupert, obtained from the Canadian ansport Commission. To be competitive with Japanese smelters, every- hing else being equal, transport costs for concentrate and smelter upplies delivered to Yukon and B.C. smelters and for metal outputs from ese smelters to Japan must not exceed the cost of shipping concentrate om Yukon mines to Japan. In this comparison the cost of delivering ilica flux and limestone to Yukon and B.C. smelters ($8.60 to $10.00 a ort ton) is ignored on the assumption that Japanese smelters face imilar transport costs for these commodities.

Marine terminal and freight charges for concentrate and metal ary according to the type and length of charter agreement, the supply d demand for specialized ships or barges on specific routes, the size d regularity of shipments and other factors. A rate of $24.00 a short on for full cargoes of concentrate in bulk carriers from Skagway or ince Rupert to Japan is a representative freight rate for 1978-79 arkets. However, the cost of shipping metal from these ports to Japan an range widely depending on size and frequency of shipments and ocean eight market conditions. For instance, bulk carriers which are bottom

loaded with metal could be chartered for $24.00 a ton given that forestry products will be top loaded in the same vessel for the Japanese market. However, if general purpose freighters in break-bulk trades are chartered for single or multiple voyage trips the marine freight rate on refined metal could range upwards from $24.00 a ton. Hence rates of $24.00, $36.00 and $48.00 a ton are used in the analysis. Metal shipping costs to other markets could fall into or exceed this range. For the shipment of concentrate in barges from Skagway to Prince Rupert, a rate including terminal costs is estimated at $11.00 a short ton for dedicated barge service.

Unit truck and rail shipping rates, in cents per ton-mile, are estimated as follows:

Table 2. Assumed Truck and Rail Freight Rates

| | cents/ton mile | miles | dollars/ton |
|---|---|---|---|
| Truck, Cyprus Anvil - Pelly River T. conc. | 10.6 | 17 | 1.80 |
| Truck, Cyprus Anvil - Whitehorse conc. | 8.0 | 238 | 19.00 |
| Truck, Howard's Pass - Pelly River T. conc. | 10.0 | 160 | 16.00 |
| Truck, Howard's Pass - Whitehorse conc. | 10.5 | 382 | 40.00 |
| Rail, Pelly River T. - Whitehorse | | | |
| 614,000 tpa conc. | 10.7 | 169 | 18.00 |
| 307,000 tpa conc. | 12.4 | 169 | 21.00 |
| Rail, Whitehorse - Skagway* | | | |
| 614,000 tpa conc. | 8.0 | 110 | 8.80 |
| 307,000 tpa conc. | 10.5 | 110 | 11.50 |
| Rail, Pelly River T. - Skagway | | | |
| 614,000 tpa metal and acid | 9.0 | 279 | 25.00 |
| 758,000 tpa conc. | 9.0 | 279 | 25.00 |
| 379,000 tpa metal and acid | 11.6 | | 34.80 |
| 307,000 tpa conc. | 12.5 | 279 | 34.80 |

* Early in 1980, WPY sought a significant rate increase on concentrates on grounds that the existing rate was not compensatory as required by and defined under the Railway Act.

## FINDINGS

Summation of transport costs (Table 3) indicates that, unless tal delivery costs to Japan are very low, smelters at most of the nadian locations considered here would bear a transport cost disadvan- ge, compared with plants at coastal Japanese sites. Similar transport st differences would apply if European coastal smelters were used for mparison. Among the three Canadian sites, and given the assumptions sted above, Whitehorse is the most favourable site with regard to ansport costs where the market area lies offshore, such as in Japan. only Yukon and B.C. transport costs are considered (Table 4), White- rse maintains its cost advantage over other sites.

The above determination would be modified if a significant are of metal is sold in central Canada and the central-eastern U.S.A. ng transcontinental rail hauls are employed to deliver base metals om western smelters to eastern markets both in Canada and the U.S. e Prince Rupert/Kitimat region, which is served by the C.N. Rail rthern mainline, is particularly well situated for cross-country hauls ereas Whitehorse lacks a continental rail connection. If all metal is rketed in North America, an approximate estimate indicates that a itehorse smelter would maintain its transport cost advantage under tion A but would lose its transport cost advantage to a Prince Rupert te under Option B, given ocean barge and handling costs of $15.00 a n of metal between Skagway and Prince Rupert. The principal advantage a direct rail connection at the smelter is the capability of shipping rload quantities of metal directly from the smelter as required to a rge number of consumers throughout the central and eastern North erican market. Hence transport bottlenecks at inter-modal transfer ints are eliminated and distribution is simple because of the extensive il network.

In estimating rail rates on an extension of the WPY from itehorse to Pelly River Terminal, lower unit rail rates are assumed der the B set than under the A option set, because of the doubling of affic volume under the B option. As a consequence any transport cost sadvantage of a smelter at Pelly River Terminal relative to a Japanese elter decreases considerably under B-3 relative to A-3 (Table 3). The ucking of smelter products from Pelly River to existing rail head at itehorse was not considered as a viable option because of the large nnage of sulphuric acid to be shipped from Pelly River Terminal to agway. Hence the Pelly River Terminal Smelter is predicated on cons- uction of the Yukon rail extension.

Table 3. Estimated Transport Cost Advantages (Disadvantages) of B.C. and Yukon Smelter sites versus a Japenese Coastal Smelter

| Option | Smelter Location | Shipping costs, metal to Japan<br>$24/ton | <br>$36/ton | <br>$48/ton |
|---|---|---|---|---|
| | | $ millions per annum | | |
| A-1 | Prince Rupert | 1.4 | (1.4) | (3.2) |
| A-2 | Prince Rupert | 0.7 | (1.1) | (2.9) |
| A-3 | Pelly River Term. | 1.1 | (0.7) | (2.5) |
| A-4 | Whitehorse | 2.8* | 1.0 | (0.8) |
| A-5 | Whitehorse | 2.8* | 1.0 | (0.8) |
| B-1 | Prince Rupert | 0.7 | (2.5) | (6.4) |
| B-2 | Prince Rupert | 0.8 | (2.8) | (6.4) |
| B-3 | Pelly River Term. | 3.3 | (0.3) | (3.9) |
| B-4 | Whitehorse | 6.2 | 2.6 | (1.0) |
| B-5 | Whitehorse | 5.7 | 2.1 | (1.5) |

* Least cost case under each option set is underlined.

Table 4. Estimated Total Transport Costs* Under Options A-1 to A-5 and B-1 to B-5.

| Option | Smelter Location | Total Transport Charges $ millions per annum |
|---|---|---|
| A-0 | Concentrate to Japan | 16.7 |
| A-1 | Prince Rupert | 12.8 |
| A-2 | Prince Rupert | 14.6 |
| A-3 | Pelly R. Terminal | 14.1 |
| A-4 | Whitehorse | 10.3** |
| A-5 | Whitehorse | 12.5 |
| B-0 | Concentrate to Japan | 37.4 |
| B-1 | Prince Rupert | 29.5 |
| B-2 | Prince Rupert | 25.9 |
| B-3 | Pelly River Terminal | 23.4 |
| B-4 | Whitehorse | 22.4** |
| B-5 | Whitehorse | 22.8 |

* Excludes marine shipments of metal.
** Least cost option is underlined.

Under the rates assumed, there is only a small cost difference ween trucking concentrate from Howard's Pass directly to a Whitehorse lter and using a truck-rail system with transfer to rail at Pelly er Terminal. The difference may not be significant given that l rates are not precisely known. However, the advantage of an initial ,000 tpy smelter complex at Whitehorse is that a Yukon rail extension ld not be required. With development of the Howard's Pass property, ansion of the Whitehorse smelter and construction of a Yukon rail ension could be considered as options to support mine and industrial elopment.

## CONCLUSIONS

Among the smelter sites considered for the processing of Yukon lead and zinc concentrate, Whitehorse is the most favourable with regard to transport costs given the basic assumptions of the cost model.

This conclusion would be modified if a significant share of metal outputs are marketed in North America or Europe. Final definition of transport cost associated with smelting of Yukon lead and zinc concentrates in the Yukon and B.C. relative to other locations requires a clear definition of long-term markets for both metal and sulphuric acid outputs and the economies that can be achieved in product transport to these markets. These costs should be integrated in a final feasibility report on Northwestern Canadian lead and zinc smelter opportunities.

May 30, 1980

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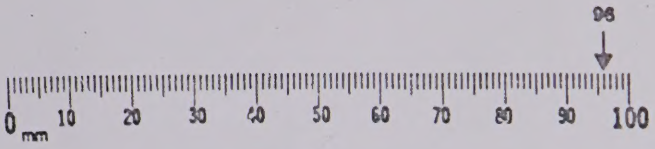

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